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New Physics from U(3)-Family Nonet Higgs Boson Scenario*

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Abstract

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New Physics from U(3)-Family Nonet Higgs Boson Scenario

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Abstract

Being inspired by a phenomenological success of a charged lepton mass formula, a model with U(3)-family nonet Higgs bosons is proposed. Here, the Higgs bosons ϕ_L (ϕ_R) couple only between light fermions (quarks and leptons) f_L (f_R) and super-heavy vector-like fermions F_R (F_L), so that the model leads to a seesaw-type mass matrix $M_f \simeq m_L M_F^{-1} m_R$ for quarks and leptons $f = u, d, \nu$ and e. Lower bounds of the physical Higgs boson masses are deduced from the present experimental data and possible new physics from the present scenario is speculated.

1 Motives

One of my dissatisfactions with the standard model is that for the explanation of the mass spectra of quarks and leptons, we must choose the coefficients y_{ij}^f in the Yukawa coupling $\sum_f \sum_{i,j} \overline{f}_L^i f_{jR} \langle\phi^0\rangle$ ($f = \nu, e, u, d$, and i, j are family indices) "by hand". In order to reduce this dissatisfaction, for example, let us suppose $\mathrm{U}(3)_{family}$ nonet Higgs fields which couple with fermions as $\sum_f \sum_{i,j} \overline{f}_L^i \langle\phi_i^{0j}\rangle f_{jR}$. Unfortunately, we know that the mass spectra of up- and down-quarks and charged leptons are not identical and the Kobayashi-Maskawa [1] (KM) matrix is not a unit matrix. Moreover, we know that in such multi-Higgs models, in general, flavor changing neutral currents (FCNC) appear unfavorably.

Nevertheless, I would like to dare to challenge to a model with $\mathrm{U}(3)_{family}$ nonet Higgs bosons which leads to a seesaw-type quark and lepton mass matrix

$$M_f \simeq m_L M_F^{-1} m_R \ . \tag{1}$$

My motives are as follows.

One of the motives is a phenomenological success of a charged lepton mass relation [2]

$$m_e + m_\mu + m_\tau = \frac{2}{3}(\sqrt{m_e} + \sqrt{m_\mu} + \sqrt{m_\tau})^2 \ , \tag{2}$$

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which predicts $m_\tau = 1776.96927 \pm 0.00052 \pm 0.00005$ MeV for the input values [3] of $m_e = 0.51099906 \pm 0.00000015$ MeV and $m_\mu = 105.658389 \pm 0.000034$ MeV (the first and second errors in (1.2) come from the errors of m_μ and m_e, respectively). Recent measurements [4] of tau lepton mass $m_\tau = 1776.96^{+0.18+0.20}_{-0.19-0.16}$ MeV excellently satisfies the charged lepton mass relation (2). An attempt to derive the mass relation (2) from a Higgs model has been tried [5]: We assumed $\mathrm{U}(3)_{family}$ nonet Higgs bosons ϕ_i^j $(i,j=1,2,3)$, whose potential is given by

$$V(\phi) = \mu^2 \mathrm{Tr}(\phi\phi^\dagger) + \frac{1}{2}\lambda \left[\mathrm{Tr}(\phi\phi^\dagger)\right]^2 + \eta \phi_s \phi_s^* \mathrm{Tr}(\phi_{oct}\phi_{oct}^\dagger) \ . \tag{3}$$

Here, for simplicity, the $\mathrm{SU}(2)_L$ structure of ϕ has been neglected, and we have expressed the nonet Higgs bosons ϕ_i^j by the form of 3×3 matrix,

$$\phi = \phi_{oct} + \frac{1}{\sqrt{3}}\phi_s \, \mathbf{1} \ , \tag{4}$$

where ϕ_{oct} is the octet part of ϕ, i.e., $\mathrm{Tr}(\phi_{oct}) = 0$, and $\mathbf{1}$ is a 3×3 unit matrix. For $\mu^2 < 0$, conditions for minimizing the potential (3) lead to the relation

$$v_s^* v_s = \mathrm{Tr}\left(v_{oct}^\dagger v_{oct}\right) \ , \tag{5}$$

together with $v = v^\dagger$, where $v = \langle\phi\rangle$, $v_{oct} = \langle\phi_{oct}\rangle$ and $v_s = \langle\phi_s\rangle$, so that we obtain the relation

$$\mathrm{Tr}\left(v^2\right) = \frac{2}{3}\left[\mathrm{Tr}(v)\right]^2 \ . \tag{6}$$

If we assume a seesaw-like mechanism for charged lepton mass matrix M_e, $M_e \simeq m M_E^{-1} m$, with $m \propto v$ and heavy lepton mass matrix $M_E \propto \mathbf{1}$, we can obtain the mass relation (2).

Another motives is a phenomenological success [6] of quark mass matrices with a seesaw-type form (1), where

$$m_L \propto m_R \propto M_e^{1/2} \equiv \begin{pmatrix} \sqrt{m_e} & 0 & 0 \\ 0 & \sqrt{m_\mu} & 0 \\ 0 & 0 & \sqrt{m_\tau} \end{pmatrix} \ , \tag{7}$$

$$M_F \propto \mathbf{1} + b_F e^{i\beta_F} 3X \equiv \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} + b_F e^{i\beta_F} \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix} \ . \tag{8}$$

The model can successfully provide predictions for quark mass ratios (not only the ratios m_u/m_c, m_c/m_t, m_d/m_s and m_s/m_b, but also m_u/m_d, m_c/m_s and m_t/m_b) and KM matrix parameters.

These phenomenological successes can be reasons why the model with a $\mathrm{U}(3)_{family}$ nonet Higgs bosons, which leads to a seesaw-type mass matrix (1), should be taken seriously.

2 Outline of the model

The model is based on SU(2)$_L\times$ SU(2)$_R\times$U(1)$_Y\times$U(3)$_{family}$ [7] symmetries. These symmetries except for U(3)$_{family}$ are gauged. The prototype of this model was investigated by Fusaoka and the author [8]. However, their Higgs potential leads to massless physical Higgs bosons, so that it brings some troubles into the theory. In the present model, the global symmetry U(3)$_{family}$ will be broken explicitly, and not spontaneously, so that massless physical Higgs bosons will not appear.

The quantum numbers of our fermions and Higgs bosons are summarized in Table I.

Table I. Quantum numbers of fermions and Higgs bosons

	Y	SU(2)$_L$	SU(2)$_R$	U(3)$_{family}$
f_L	$(\nu,\, e)_L^{Y=-1}$, $(u,\, d)_L^{Y=1/3}$	**2**	**1**	**3**
f_R	$(\nu,\, e)_R^{Y=-1}$, $(u,\, d)_R^{Y=1/3}$	**1**	**2**	**3**
F_L	$N_L^{Y=0}$, $E_L^{Y=-2}$, $U_L^{Y=4/3}$, $D_L^{Y=-2/3}$	**1**	**1**	**3**
F_R	$N_R^{Y=0}$, $E_R^{Y=-2}$, $U_R^{Y=4/3}$, $D_R^{Y=-2/3}$	**1**	**1**	**3**
ϕ_L	$(\phi^+, \phi^0)_L^{Y=1}$	**2**	**1**	**8+1**
ϕ_R	$(\phi^+, \phi^0)_R^{Y=1}$	**1**	**2**	**8+1**
Φ_F	$\Phi_0^{Y=0}$, $\Phi_X^{Y=0}$	**1**	**1**	**1**, **8**

Note that in our model there is no Higgs boson which belongs to (**2**, **2**) of SU(2)$_L\times$SU(2)$_R$. This guarantees that we obtain a seesaw-type mass matrix (2) by diagonalization of a 6×6 mass matrix for fermions (f, F):

$$\left(\begin{array}{cc} 0 & m_L \\ m_R & M_F \end{array} \right) \Longrightarrow \left(\begin{array}{cc} M_f & 0 \\ 0 & M_F' \end{array} \right) , \tag{9}$$

where $M_f \simeq -m_L M_F^{-1} m_R$ and $M_F' \simeq M_F$ for $M_F \gg m_L$, m_R. (See Fig. 1.)

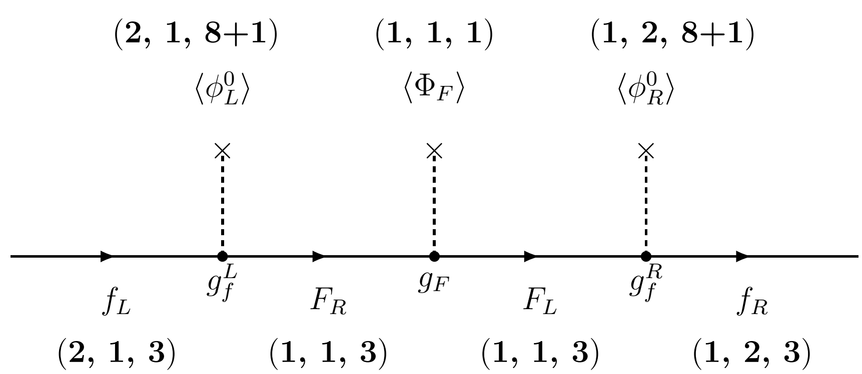

Fig. 1. Mass generation mechanism of $M_f \simeq m_L M_F^{-1} m_R$.

3 Higgs potential and "nonet" ansatz

We assume that $\langle\phi_R\rangle \propto \langle\phi_L\rangle$, i.e., each term in $V(\phi_R)$ takes the coefficient which is exactly proportional to the corresponding term in $V(\phi_L)$. This assumption means that there is a kind of "conspiracy" between $V(\phi_R)$ and $V(\phi_L)$. However, in the present stage, we will not go into this problem moreover. Hereafter, we will drop the index L in ϕ_L.

The potential $V(\phi)$ is given by

$$V(\phi) = V_{nonet} + V_{Oct\cdot Singl} + V_{SB} \ , \tag{10}$$

where V_{nonet} is a part of $V(\phi)$ which satisfies a "nonet" ansatz stated below, $V_{Oct\cdot Singl}$ is a part which violates the "nonet" ansatz, and V_{SB} is a term which breaks $\mathrm{U}(3)_{family}$ explicitly.

The "nonet" ansatz is as follows: the octet component ϕ_{oct} and singlet component ϕ_s of the Higgs scalar fields ϕ_L (ϕ_R) always appear with the combination of (4) in the Lagrangian. Under the "nonet" ansatz, the $\mathrm{SU}(2)_L$ invariant (and also $\mathrm{U}(3)_{family}$ invariant) potential V_{nonet} is, in general, given by

$$\begin{aligned} V_{nonet} = \mu^2 \mathrm{Tr}(\overline{\phi}\phi) + \frac{1}{2}\lambda_1(\overline{\phi}_i^j\phi_j^i)(\overline{\phi}_k^l\phi_l^k) \\ +\frac{1}{2}\lambda_2(\overline{\phi}_i^j\phi_k^l)(\overline{\phi}_l^k\phi_j^i) + \frac{1}{2}\lambda_3(\overline{\phi}_i^j\phi_k^l)(\overline{\phi}_j^i\phi_l^k) + \frac{1}{2}\lambda_4(\overline{\phi}_i^j\phi_j^k)(\overline{\phi}_k^l\phi_l^i) \\ +\frac{1}{2}\lambda_5(\overline{\phi}_i^j\phi_l^i)(\overline{\phi}_k^l\phi_j^k) + \frac{1}{2}\lambda_6(\overline{\phi}_i^j\phi_j^k)(\overline{\phi}_l^i\phi_k^l) + \frac{1}{2}\lambda_7(\overline{\phi}_i^j\phi_k^l)(\overline{\phi}_j^k\phi_l^i) \ , \end{aligned} \tag{11}$$

where $(\overline{\phi}\phi) = \phi^-\phi^+ + \overline{\phi}^0\phi^0$.

On the other hand, the "nonet ansatz" violation terms $V_{Oct\cdot Singl}$ are given by

$$\begin{aligned} V_{Oct\cdot Singl} = \eta_1(\overline{\phi}_s\phi_s)\mathrm{Tr}(\overline{\phi}_{oct}\phi_{oct}) + \eta_2\left(\overline{\phi}_s(\phi_{oct})_i^j\right)\left((\overline{\phi}_{oct})_j^i\phi_s\right) \\ +\eta_3\left(\overline{\phi}_s(\phi_{oct})_i^j\right)\left(\overline{\phi}_s(\phi_{oct})_j^i\right) + \eta_3^*\left((\overline{\phi}_{oct})_i^j\phi_s\right)\left((\overline{\phi}_{oct})_j^i\phi_s\right) \ . \end{aligned} \tag{12}$$

For a time, we neglect the term V_{SB} in (10). For $\mu^2 < 0$, conditions for minimizing the potential (10) lead to the relation

$$v_s^2 = \mathrm{Tr}(v_{oct}^2) = \frac{-\mu^2}{2(\lambda_1+\lambda_2+\lambda_3) + (\eta_1+\eta_2+2\eta_3)} \ , \tag{13}$$

under the conditions $\lambda_4+\lambda_5+2(\lambda_6+\lambda_7)=0$, and $v = v^\dagger$, where we have put $\eta_3 = \eta_3^*$ for simplicity.

Hereafter, we choose the family basis as

$$v = \left(\begin{array}{ccc} v_1 & 0 & 0 \\ 0 & v_2 & 0 \\ 0 & 0 & v_3 \end{array}\right) \ . \tag{14}$$

For convenience, we define the parameters z_i as

$$z_i \equiv \frac{v_i}{v_0} = \sqrt{\frac{m_i^e}{m_e+m_\mu+m_\tau}} \ , \tag{15}$$

where

$$v_0 = (v_1^2 + v_2^2 + v_3^2)^{1/2} \ , \tag{16}$$

so that $(z_1, z_2, z_3) = (0.016473, 0.23687, 0.97140)$.

We define two independent diagonal elements of ϕ_{oct} as

$$\begin{aligned} \phi_x &= x_1\phi_1^1 + x_2\phi_2^2 + x_3\phi_3^3 \ , \\ \phi_y &= y_1\phi_1^1 + y_2\phi_2^2 + y_3\phi_3^3 \ , \end{aligned} \tag{17}$$

where the coefficients x_i and y_i are given by

$$x_i = \sqrt{2}z_i - 1/\sqrt{3} \ , \tag{18}$$

$$(y_1, y_2, y_3) = (x_2 - x_3, x_3 - x_1, x_1 - x_2)/\sqrt{3} \ . \tag{19}$$

Then, the replacement $\phi^0 \to \phi^0 + v$ means that $\phi_s^0 \to \phi_s^0 + v_s$; $\phi_x^0 \to \phi_x^0 + v_x$; $\phi_y^0 \to \phi_y^0$; $(\phi^0)_i^j \to (\phi^0)_i^j \ \ (i \neq j)$, where $v_i = v_s/\sqrt{3} + x_i v_x$. This means that even if we add a term

$$V_{SB} = \xi \left(\overline{\phi}_y \phi_y + \sum_{i \neq j} \overline{\phi}_i^j \phi_j^i \right) \ , \tag{20}$$

in the potential $V_{nonet} + V_{Oct \cdot Singl}$, the relation (13) are still unchanged.

4 Physical Higgs boson masses

For convenience, we define:

$$\begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix} = \frac{1}{\sqrt{2}} \begin{pmatrix} i\sqrt{2}\,\chi^+ \\ H^0 - i\chi^0 \end{pmatrix} \ , \tag{21}$$

$$\begin{pmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \end{pmatrix} = \begin{pmatrix} z_1 & z_2 & z_3 \\ z_1 - \sqrt{\frac{2}{3}} & z_2 - \sqrt{\frac{2}{3}} & z_3 - \sqrt{\frac{2}{3}} \\ \sqrt{\frac{2}{3}}(z_2 - z_3) & \sqrt{\frac{2}{3}}(z_3 - z_1) & \sqrt{\frac{2}{3}}(z_1 - z_2) \end{pmatrix} \begin{pmatrix} \phi_1^1 \\ \phi_2^2 \\ \phi_3^3 \end{pmatrix} \ . \tag{22}$$

Then, we obtain masses of these Higgs bosons which are sumalized in Table II.

Table II. Higgs boson masses squared in unit of $v_0^2 = (174 \text{ GeV})^2$, where $\overline{\xi} = \xi/v_0^2$. For simplicity, the case of $\lambda_4 = \lambda_5 = \lambda_6 = \lambda_7 = 0$ are tabled.

ϕ	H^0	χ^0	$\chi^\pm$
$m^2(\phi_1)$	$2(\lambda_1 + \lambda_2 + \lambda_3)$ $+\eta_1 + \eta_2 + 2\eta_3$	0	0
$m^2(\phi_2)$	$-(\eta_1 + \eta_2 + 2\eta_3)$	$-2(\lambda_3 + 2\eta_3)$	$-(\lambda_2 + \lambda_3 + \eta_2 + 2\eta_3)$
$m^2(\phi_3)$	$\overline{\xi}$	$\overline{\xi} - 2(\lambda_3 + \eta_3)$	$\overline{\xi} - [\lambda_2 + \lambda_3 + \frac{1}{2}(\eta_2 + 2\eta_3)]$
$m^2(\phi_i^j)$	$= m^2(H_3^0)$	$= m^2(\chi_3^0)$	$= m^2(\chi_3^\pm)$

The massless states $\chi_1^\pm$ and χ_1^0 are eaten by weak bosons $W^\pm$ and Z^0, so that they are not physical bosons. The mass of $W^\pm$ is given by $m_W^2 = g^2 v_0^2/2$, so that the value of v_0 defined by (16) is $v_0 = 174$ GeV.

5 Interactions of the Higgs bosons

(A) Interactions with gauge bosons

Interactions of ϕ_L with gauge bosons are calculated from the kinetic term $\mathrm{Tr}(D_\mu \overline{\phi}_L D^\mu \phi_L)$. The results are as follows :

$$
\begin{aligned}
H_{EW} = +i\left(eA_\mu + \frac{1}{2}g_z \cos 2\theta_W Z_\mu\right) \mathrm{Tr}(\chi^- \overleftrightarrow{\partial}^\mu \chi^+) + \frac{1}{2}g_z Z_\mu \mathrm{Tr}(\chi^0 \overleftrightarrow{\partial}^\mu H^0) \\
+\frac{1}{2}g\left\{W_\mu^+[\mathrm{Tr}(\chi^- \overleftrightarrow{\partial}^\mu H^0) - i(\chi^- \overleftrightarrow{\partial}^\mu \chi^+) + \mathrm{h.c.}\right\} \\
+\frac{1}{2}\left(2g m_W W_\mu^- W^{+\mu} + g_z m_Z Z_\mu Z^\mu\right) H_1^0 \ ,
\end{aligned}
\tag{23}
$$

where $g_z = g/\cos\theta_W$ and $\chi_1^\pm = \chi_1^0 = 0$.

Note that the interactions of H_1^0 are exactly same as that of H^0 in the standard model.

(B) Three-body interactions among Higgs bosons

$$
H_{\phi\phi\phi} = \frac{1}{2\sqrt{2}}\frac{m^2(H_1^0)}{v_0} H_1^0 \mathrm{Tr}(H^0 H^0) + \frac{1}{2\sqrt{2}}\frac{m^2(H_2^0)}{v_0}\left(H_1^0 H_2^0 H_2^0 - H_1^0 H_1^0 H_2^0\right) + \ \cdots \ . \tag{24}
$$

The full expression will be given elsewhere.

(C) Interactions with fermions

Our Higgs particles ϕ_L do not have interactions with light fermions f at tree level, and they can couple only between light fermions f and heavy fermions F. However, when the 6×6 fermion mass matrix is diagonalized as (9), the interactions of ϕ_L with the physical fermion states (mass eigenstates) become

$$
\begin{pmatrix} 0 & \Gamma_L \\ 0 & 0 \end{pmatrix} \Longrightarrow \begin{pmatrix} \Gamma_{11} & \Gamma_{12} \\ \Gamma_{21} & \Gamma_{22} \end{pmatrix} , \tag{25}
$$

where $\Gamma_L = y_f \phi_L$, and

$$
\Gamma_{11} \simeq U_L^f \phi_L v^{-1} U_L^{f\dagger} D_f \ . \tag{26}
$$

For charged leptons, since $U_L^e = \mathbf{1}$, the interactions of ϕ_L^0 are given by

$$
H_{Yukawa}^{lepton} = \frac{1}{2\sqrt{2}}\sum_{i,j}\left[\overline{e}_i(a_{ij} - b_{ij}\gamma_5)e_j (H^0)_i^j + i\overline{e}_i(b_{ij} - a_{ij}\gamma_5)e_j(\chi^0)_i^j\right] , \tag{27}
$$

$$
a_{ij} = \frac{m_i}{v_i} + \frac{m_j}{v_j} , \quad b_{ij} = \frac{m_i}{v_i} - \frac{m_j}{v_j} . \tag{28}
$$

Therefore, in the pure leptonic modes, the exchange of ϕ_L cannot cause family-number non-conservation.

For quarks, in spite of $U_L^q \neq \mathbf{1}$, the Higgs boson H_1^0 still couples with quarks q_i diagonally:

$$
H_{Yukawa}^{quark} = \frac{1}{\sqrt{2}}\sum_i \frac{m_i^q}{v_0}(\overline{q}_i q_i) H_1^0 \ + \ \cdots \ . \tag{29}
$$

However, the dotted parts which are interaction terms of ϕ_2, ϕ_3 and ϕ_i^j $(i \neq j)$ cause family-number non-conservation.

6 Family-number changing and conserving neutral currents

(A) Family-number changing neutral currents

In general, the Higgs boson H_1^0 do not contribute to flavor-changing neutral currents (FCNC), and only the other bosons contribute to $\overline{P}^0$-P^0 mixing. The present experimental values [3] $\Delta m_K = m(K_L) - m(K_S) = (0.5333 \pm 0.0027) \times 10^{10}\ \hbar \mathrm{s}^{-1}$, $|\Delta m_D| = |m(D_1^0) - m(D_2^0)| < 20 \times 10^{10}\ \hbar \mathrm{s}^{-1}$, $\Delta m_B = m(D_H) - m(D_L) = (0.51 \pm 0.06) \times 10^{12}\ \hbar \mathrm{s}^{-1}$, and so on, give the lower bound of Higgs bosons $m(H_2^0),\ m(\chi_2^0) > 10^5$ GeV. For the special case of $m(H) = m(\chi)$, we obtain the effective Hamiltonian

$$H_{FCNC} = \frac{1}{3}\left(\frac{1}{m^2(H_2^0)} - \frac{1}{m^2(H_3^0)}\right) \sum_{i \neq j} \frac{m_i m_j}{v_0^2} \sum_k \left(\frac{1}{z_k^2} + \frac{z_k - z_l - z_m}{z_1 z_2 z_3}\right)$$

$$\times (U_i^k U_j^{k*})^2 \left[(\overline{f}_i f_j)^2 - (\overline{f}_i \gamma_5 f_j)^2\right] , \tag{30}$$

where (k, l, m) are cyclic indices of $(1, 2, 3)$, so that the bound can reduce to $m(H_2^0) = m(\chi_2^0) >$ a few TeV. Note that FCNC can highly be suppressed if $m(H_2) \simeq m(H_3)$.

(B) Family-number conserving neutral currents

The strictest restriction on the lower bound of the Higgs boson masses comes from

$$\frac{B(K_L \to e^\pm \mu^\mp)}{B(K_L \to \pi^0 \ell^\pm \nu)} \simeq \left(\frac{v_0}{m_H}\right)^4 \times 1.94 \times 10^{-6} . \tag{31}$$

The present data [3] $B(K_L \to e^\pm \mu^\mp)_{exp} < 3.3 \times 10^{-11}$ leads to the lower bound $m_{H3}/v_0 > 12$, i.e., $m_{H3} > 2.1$ TeV.

7 Productions and decays of the Higgs bosons

As stated already, as far as our Higgs boson H_1^0 is concerned, it is hard to distinguish it from H^0 in the standard model. We discuss what is a new physics expected concerned with the other Higgs bosons.

(A) Productions

Unfortunately, since masses of our Higgs bosons ϕ_2 and ϕ_3 are of the order of a few TeV, it is hard to observe a production

$$\begin{aligned} e^+ + e^- \to Z^* \to (H^0)_i^j \qquad &+\ (\chi^0)_j^i , \\ \hookrightarrow f_i + \overline{f}_j \qquad &\hookrightarrow f_j + \overline{f}_i , \end{aligned} \tag{32}$$

even in e^+e^- super linear colliders which are planning in the near future. Only a chance of the observation of our Higgs bosons ϕ_i^j is in a production

$$u \to t + (\phi)_1^3 , \tag{33}$$

at a super hadron collider with several TeV beam energy, for example, at LHC, because the coupling a_{tu} (b_{tu}) is sufficiently large:

$$a_{tu} \simeq \frac{m_t}{v_3} + \frac{m_u}{v_1} = 1.029 + 0.002, \tag{34}$$

[c.f. $a_{bd} \simeq (m_b/v_3) + (m_d/v_1) = 0.026 + 0.003$].

(B) Decays

Dominant decay modes of $(H^0)_3^2$ and $(H^0)_3^1$ are hadronic ones, i.e., $(H^0)_3^2 \to t\overline{c}$, $b\overline{s}$ and $(H^0)_3^1 \to t\overline{u}$, $b\overline{d}$. Only in $(H^0)_2^1$ decay, a visible branching ratio of leptonic decay is expected:

$$\Gamma(H_2^1 \to c\overline{u}) : \Gamma(H_2^1 \to s\overline{d}) : \Gamma(H_2^1 \to \mu^- e^+)$$
$$\simeq 3\left[\left(\frac{m_c}{v_2}\right)^2 + \left(\frac{m_u}{v_1}\right)^2\right] : 3\left[\left(\frac{m_s}{v_2}\right)^2 + \left(\frac{m_d}{v_1}\right)^2\right] : \left[\left(\frac{m_\mu}{v_2}\right)^2 + \left(\frac{m_e}{v_1}\right)^2\right]$$
$$= 73.5\% : 24.9\% : 1.6\%. \tag{35}$$

8 Summary

We have proposed a U(3)-family nonet Higgs boson scenario, which leads to a seesaw-type quark and lepton mass matrix $M_f \simeq m_L M_F^{-1} m_R$.

It has been investigated what a special form of the the potential $V(\phi)$ can provide the relation

$$m_e + m_\mu + m_\tau = \frac{2}{3}(\sqrt{m_e} + \sqrt{m_\mu} + \sqrt{m_\tau})^2 \ ,$$

and the lower bounds on the masses of ϕ_L have been estimated from the data of P^0-$\overline{P}^0$ mixing and rare meson decays.

Unfortunately, the Higgs bosons, except for H_1^0, in the present scenario are very heavy, i.e., $m_H \simeq m_\chi \sim$ a few TeV. We expect that our Higgs boson $(\phi^0)_1^3$ will be observed through the reaction $u \to t + (\phi^0)_1^3$ at LHC.

The present scenario is not always satisfactory from the theoretical point of view:
(1) A curious ansatz, the "nonet" ansatz, has been assumed.
(2) The potential includes an explicitly symmetry breaking term V_{SB}.

These problems are future tasks of our scenario.

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